Aggression and Violent Behavior 19 (2014) 699–707

Contents lists available at ScienceDirect

Aggression and Violent Behavior

# Temporal and geographic trends in homicide and suicide rates in Mexico, from 1998 through 2012☆

Iwin Leenen [a,*], Arturo Cervantes-Trejo [b,c]

[a] Faculty of Medicine, National Autonomous University of Mexico, Mexico
[b] Carlos Peralta Chair of Public Health, Anahuac University, Mexico
[c] National Institute for the Evaluation of Education (INEE), Mexico

ARTICLE INFO

*Article history:*
Received 21 August 2014
Accepted 27 September 2014
Available online 22 October 2014

*Keywords:*
Homicides
Suicides
Violence
Mexico
Generalized linear mixed model

ABSTRACT

We analyze and discuss the temporal and geographic trends in the officially registered violence-related deaths (216,462 homicides and 77,334 suicides) that occurred between 1998 and 2012 on Mexican territory. Mixed-effects logistic regression models were fitted, separately for men and women and different age groups, where (a) the evolution of the log-odds of the homicide and suicide rates over time was assumed to follow a piecewise linear function and (b) the geographic variation in the latter function was accounted for by random effects associated with the 2,456 municipalities in the country. The homicide analyses show that, although the absolute homicide rates strongly differ between men and women (with a factor of about 10), the overall temporal trends for women between 16 and 49 years and men between 16 and 60 years of age are remarkably similar, in that the rates decrease until 2007 and strongly increase afterwards. In absolute terms, men between 20 and 49 years form the most vulnerable group with an averaged homicide rate in 2012 of over 40 per 100,000. Geographically, homicide rates in 2012 are found to be the highest in the states known for the drugs-related violence, which are also the states where the increase between 2007 and 2010 was the strongest. As to the suicide rates, a steady increase was found over the 15-year study period in females between 12 and 39 years and in men between 12 and 49 years of age, while in the other age groups, the rates remained relatively constant. On average, a completed suicide is about eight times more likely in adult men than in adult women (although important interactions with age should be considered); men between 20 and 49 years of age, together with those over 75, are most vulnerable, with an average suicide rate of over 10 per 100,000 in 2012. In order to decrease the levels of violence in Mexico, moving beyond the political rhetoric and the implementation of evidence-based prevention programs are imperative.



**Contents**



## 1. Introduction

In 1996, the World Health Organization defined violence as "the intentional use of physical force or power, threatened or actual, against oneself, another person, or against a group or community, which either results in or has a high likelihood of resulting in injury, death,

☆ The authors gratefully acknowledge the assistance of Luis Chias Becerril of the Institute of Geography of the National Autonomous University of Mexico in constructing the maps in Fig. 3.

* Corresponding author.
*E-mail addresses:* iwin.leenen@gmail.com (I. Leenen), cervantes@post.harvard.edu (A. Cervantes-Trejo).

http://dx.doi.org/10.1016/j.avb.2014.09.004
1359-1789/

psychological harm, maldevelopment or deprivation" (as cited in Dahlberg and Krug (2002), p. 5). Since the Forty-Ninth World Health Assembly [WHA] (1996) declared violence a major and growing global public health problem, many international efforts, such as the Global Burden of Disease study (Lozano et al., 2012; Murray et al., 2012), the World Report on Violence and Health (Krug, Dahlberg, Mercy, Zwi, & Lozano, 2002) and the associated Global Campaign on Violence Prevention (Violence Prevention Alliance [VPA], 2012), have brought evidence-based violence prevention onto the public health agenda (see also, Rutherford, Zwi, Grove, and Butchart (2007a, 2007b)).

Every year in the world, an estimated 1.34 million violent deaths occur from intentional injury, of which around 880,000 are self-inflicted (i.e., suicides) and 460,000 are other-inflicted (i.e., homicides; Lozano et al., 2012). Worldwide, both homicide and suicide rank among the leading causes of death among those aged 15–44 years. Experts agree that deaths, injuries and disabilities due to violence are expected to increase in the world, especially in low- and middle-income countries (United Nations Office on Drugs & Crime [UNODC], 2014; VPA, 2012). Recent data show that Central America, together with Southern Africa, has the highest homicide rates in the world, reaching above 24 victims per 100,000 population in 2012, whereas the global, worldwide homicide rate amounted to 6.2 per 100,000; when considering the five global regions defined by the United Nations, homicide rates are highest in the Americas with 16.3 homicides per 100,000 as compared to 2.9 in Asia, 3.0 in Oceania and Europe, and 12.5 in Africa (UNODC, 2014). Conversely, suicide rates in the Americas with 7.9 per 100,000 are—together with Africa and the Eastern Mediterranean region—considerably lower as compared to Europe, South-East Asia (which includes India), and the Western Pacific region (including China and Japan), where about 14 suicides occur per 100,000 population (Värnik, 2012).

In the last decade, mortality from violence, and particularly homicide, has strongly increased in Mexico, which moved the country into the group of Latin American countries with the highest rates of violence-related deaths (Gawryszewski, Sanhueza, Martinez-Piedra, Escamilla, & Marinho de Souza, 2012; UNODC, 2014). Although this increase has been amply documented and discussed in the popular as well as the academic press (Dube, Dube, & García-Ponce, 2013; González-Pérez et al., 2012; Hernández-Bringas & Flores-Arenales, 2011; Salama, 2013; Vilalta, 2013, 2014), the evolution over time has been studied either globally or at the level of distressed areas or states. The present study examines the overall temporal pattern of change in homicides and suicides since 1998 in Mexico, segregated by gender and age groups, and how this temporal evolution spatially distributes at the aggregate level of municipalities. The findings are discussed in relation to existing literature on the psychological and sociological impact of living and growing up in a violence-stricken neighborhood. We conclude with some implications for policy-making.

## 2. Method

### 2.1. Data

The following two sources of data were combined in the present project. Both sources are made available by Mexico's National Institute of Statistics, Geography and Information (Instituto Nacional de Estadística y Geografía [INEGI], n.d.). On the one hand, we downloaded population counts from the Mexican censuses in the years 2000, 2005, and 2010, separated for each of the 2,456 municipalities in the country and segregated by sex and for each year of age. Subsequently, the counts by year of age were aggregated in ten age groups (0–11, 12–15, 16–19, 20–23, 24–29, 30–39, 40–49, 50–59, 60–74, and 75 or older), so that the number of individuals in each of the 20 combinations of sex and age groups (further called sex–age groups) were obtained for each municipality in each of the three census years. By linear interpolation, population counts were estimated for the other years covered by the 15 year study period.

On the other hand, we consulted the official mortality data sets of Mexico, in which, among others, details on the cause of death (classified according to the international classification of diseases ICD-10, World Health Organization [WHO], 2011), exact time of death, municipality and date of registration, and sex and age of the deceased are recorded. From this data base, we extracted all deaths classified either as homicides (i.e., categories X85–Y09, Y35, Y36, Y87.1 and Y89.9 in the ICD-10 classification) or as suicides (i.e., ICD-10 categories X60–X84 and Y87.0). The cases for which the municipality of registration was missing or for which the registration occurred more than a year after the actual decease (0.9% for homicides and 0.5% for suicides) were removed. If sex and/or age of the victim was missing (3.1% of the homicides and 0.7% of the suicides), the observation was randomly redistributed taking into account the actual distribution of sex and age in the population of homicides/suicides across the country.

Combining both sources of information resulted into a data set with the number of residents as well as the number of homicides and suicides registered in each municipality, by sex–age group, and for each year included in the study.

### 2.2. Statistical analysis

These data were analyzed, separately for homicides and suicides and for each sex–age group, by means of multilevel logistic regression models (which belong to the family of hierarchical or mixed-effects generalized linear models; see Snijders & Bosker, 2012, chap. 17; Wong & Mason, 1985). In view of the small numbers of suicides in the lowest age group (an average of 1.0 per 1,000,000 per year, boys and girls taken together) and some methodological issues in classifying child mortality as suicides (Crepeau-Hobson, 2010), we excluded children younger than 12 years of age from the analysis.

At the lowest level of the model, the number $Y_{it}$ of homicides or suicides in the sex–age group under study that occurred in municipality $i$ ($i = 1, \ldots, 2456$) during year $t$ ($t = 1998, \ldots, 2012$) is assumed to follow a binomial distribution with parameters $n_{it}$ (i.e., the number of inhabitants belonging to the given sex–age group in municipality $i$ in year $t$) and $\pi_{it}$ (i.e., the probability that an individual from this subpopulation becomes the victim of homicide or commits suicide). It is further assumed that, within municipality $i$, the log-odds of the latter probabilities follow a (continuous) piecewise linear function of time, parametrized as follows:

$$\log\left(\frac{\pi_{it}}{1-\pi_{it}}\right) = \beta_{0i} + \sum_{j=1}^{m}\beta_{ji}\left[\max\left(t,\tau_j\right)-\left(\tau_{j-1}\right)\right]I\left(t<\tau_{j-1}\right), \quad (1)$$

where $m$ denotes the number of linear pieces and $\tau_0, \ldots, \tau_m$ the breakpoints in descending order (i.e., the years where the respective linear pieces begin and end, with $\tau_0 \equiv 2012$ and $\tau_m \equiv 1998$), which are specified as constants in the analysis (see below). The indicator function $I$(*expression*) equals 1 if *expression* is true, and 0 otherwise. As illustrated in Fig. 1, the parametrization in Eq. (1) renders $\beta_{0i}$ the interpretation of the (log-odds of the) homicide or suicide rate in municipality $i$ in the year 2012, while $\beta_{ji} = (j = 1, \ldots, m)$ indicates how this rate has changed (per year) between $\tau_j$ and $\tau_{j-1}$.

Whereas at the first level the temporal evolution within municipalities is modeled, the second level specifies parameters which allow studying the variation among municipalities with regard to this temporal evolution. In particular, the between-municipality variation in each of the parameters $\beta_{ji}$ at the right-hand side of Eq. (1) is modeled as follows:

$$\beta_{ji} = \gamma_{0j} + \gamma_{Sj}X_{Si} + \gamma_{Mj}X_{Mi} + \gamma_{Lj}X_{Li} + \gamma_{Bj}X_{Bi} + u_{ji}, \quad (2)$$